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LOOP REACTOR APPARATUS AND POLYMERIZATION PROCESSES WITH MULTIPLE FEED POINTS FOR OLEFINS AND CATALYSTS

RELATED APPLICATIONS

[0001] This application claims the benefit under 35 U.S.C. § 119(e) of U.S. Provisional Patent Application No. 60/410,367 ("the '367 application") filed on September 13, 2002. The '367 application is incorporated by reference herein.

FIELD OF THE INVENTION

[0002] This invention relates to the polymerization of olefin monomers in a liquid medium, particularly in a large loop reactor used for slurry polymerization.

BACKGROUND OF THE INVENTION

[0003] Polyolefins such as polyethylene and polypropylene may be prepared by particle form polymerization, also referred to as slurry polymerization. In this technique, feed materials such as monomer and catalyst are introduced to a reactor (such as a loop reactor), and a product slurry containing solid polyolefin particles in the liquid medium is taken off.

[0004] In continuous loop reactors, the various feed materials may be introduced to the loop reaction zone in various ways. For example, the monomer and catalyst may be introduced separately or together, and the monomer and catalyst may be mixed with varying amounts of diluent prior to introduction to the reaction zone. In the loop reaction zone, the monomer and catalyst become dispersed in the fluid slurry. As they circulate through the loop reaction zone in the fluid slurry, the monomer reacts at the catalyst site in a polymerization reaction. The polymerization reaction yields solid polyolefin particles in the fluid slurry.

[0005] Slurry polymerization in a loop reaction zone has proven commercially successful. The slurry polymerization technique has enjoyed international success with billions of pounds of olefin polymers being so produced annually. However, it is still desirable to design and build larger reactors.

[0006] Properties of the polymer are influenced by reactor conditions, including the concentration of monomer, during the polymerization process. In a loop polymerization process, the concentration of monomer will tend to decrease as monomer reacts to form polymer in the course of the polymerization process. In existing polymerization processes and loop reactors, the concentration of monomer has been maintained within acceptable ranges throughout the loop reaction zone with the use of a single monomer feed in the loop reactor.

[0007] The concentration of monomer in the loop reaction zone is often evaluated by measuring the concentration of monomer in the product slurry that is removed from the loop reaction zone. It is generally easier to measure monomer concentration outside the loop reaction zone than inside the loop reaction zone.

BRIEF SUMMARY OF THE INVENTION

[0008] As one aspect, a slurry polymerization process is provided. In this process, solid polyolefin particles are formed in a liquid medium. The process includes introducing an olefin monomer and a catalyst to the loop reaction zone. The catalyst must be capable of polymerizing the olefin monomer. The process also includes introducing the olefin monomer to the loop reaction zone through a plurality (two or more) of monomer feeds. The olefin monomer is introduced so that the concentration of the olefin monomer within the loop reaction zone is within a desired range. For example, by introducing the olefin monomer at multiple symmetrically-arranged feed locations, the olefin monomer concentration in a liquid diluent in the reactor may be held within a range of 1.05% or a smaller range. The variation of olefin monomer concentration around the reactor may be kept quite low, so that the standard deviation of the olefin monomer concentrations around the reactor is 0.4% or less. In some embodiments, there is at least one monomer

feed per 800 feet of reactor length, or at least one monomer feed per 18,000 gallons of reactor volume.

[0009] The process may also include withdrawing a portion of the fluid slurry as an intermediate product through a plurality of product take-offs. The catalyst may be introduced through a plurality of catalyst feeds. Preferably, the monomer feeds and the product take-offs are symmetrically arranged around the loop reaction zone. The catalyst feeds may also be symmetrically arranged around the loop reaction zone.

[0010] The process may also include measuring the concentration of the olefin monomer in the withdrawn portion of the fluid slurry, and adjusting the introduction of the olefin monomer in response to the measured concentration. The introduction of olefin monomer may be adjusted so that a different amount of the olefin monomer is fed at one monomer feed than the amount of the olefin monomer fed at another monomer feed.

[0011] As another aspect, a loop reactor apparatus is provided. The loop reactor apparatus includes a plurality of major segments, and a plurality of upper and lower minor segments. Each of the major segments is connected at an upper end to one of the upper minor segments, and is connected at a lower end by a smooth lower bend to one of the lower minor segments. In such fashion, the major and minor segments form a continuous flow path adapted to convey a fluid slurry. The flow path is substantially free from internal obstructions.

[0012] Alternatively the loop reactor apparatus may comprise a first major leg, a second major leg, a third major leg, a fourth major leg, a fifth major leg, a sixth major leg, a seventh major leg, and an eighth major leg. The apparatus may also comprise a plurality of minor segments, where each segment connects two of the major legs to each other, thereby forming a continuous flow path. The apparatus may include a first monomer feed attached to the first major leg; a first product take-off attached to the third major leg; a second monomer feed attached to the fifth major leg; a second product take-off attached to the seventh major leg; and at least one catalyst feed attached to one of the legs or segments.

[0013] The foregoing loop reactor apparatus includes at least two means for introducing an olefin monomer into the continuous flow path, a means for introducing a polymerization catalyst into the continuous flow path, and at least two means for removing a portion of the fluid slurry from the continuous flow path. The loop reactor apparatus may also include at least one means for measuring the concentration of olefin monomer in the removed portion of the fluid slurry. The measuring means is in fluid connection with the removing means. The loop reactor apparatus may also include a means for controlling the monomer introducing means. The measuring means provides a signal indicative of the measured concentration to the controlling means.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] FIG. 1 is a schematic perspective view of a loop reactor having a plurality of monomer feeds, a plurality of catalyst feeds, and a plurality of product take-offs for withdrawing a portion of the slurry.

DETAILED DESCRIPTION OF THE INVENTION

[0015] The present processes and apparatus are suitable for the homopolymerization of ethylene and the copolymerization of ethylene and a higher 1-olefin such as butene, 1-pentene, 1-hexene, 1-octene or 1-decene. A preferred process is the copolymerization of ethylene and, as a starting material, an amount of comonomer in the range of 0.01 to 10, preferably 0.01 to 5, more preferably 0.1 to 4 weight percent, wherein the comonomer is selected from the foregoing higher 1-olefins, and the weight percent is based on the total weight of ethylene and comonomer. (Such copolymers are still referred to as polyethylene). Alternatively, sufficient comonomer can be used as a starting material to give a resulting product polyolefin having an incorporated amount of comonomer in the range of 0.01 to 10, preferably 0.01 to 5, more preferably 0.1 to 4 weight percent.

[0016] The liquid medium may be a diluent for the solid polymer particles that is separate from and in addition to the unreacted monomers. Suitable diluents for the

present processes are well known in the art and include hydrocarbons which are inert and liquid or are super critical fluids under slurry polymerization conditions. Suitable hydrocarbons include isobutane, propane, n-pentane, i-pentane, neopentane and n-hexane, with isobutane being especially preferred. Alternatively, the liquid medium may be the unreacted monomer itself. For example, the present processes and apparatus may also be adapted to propylene polymerization in loop reactors. In the case of bulk polymerization of propylene, there is no separate diluent with respect to the monomer, because the monomer (propylene) serves as the liquid medium. Of course, the concentration of the olefin monomer will be much higher than when a liquid diluent is also present.

[0017] Suitable catalysts are also well known in the art. Particularly suitable is chromium oxide on a support such as silica as broadly disclosed, for instance, in Hogan and Banks, U.S. Patent No. 2,825,721 (March 1958), which is hereby incorporated by reference. Ziegler catalysts, metallocenes, and other well-known polyolefin catalysts, as well as co-catalysts, may be used. Preferably, only one catalyst is used for a given polymerization process, and the same catalyst is introduced at each of a plurality of catalyst feeds.

[0018] Additional details regarding loop reactor apparatus and polymerization processes may be found, for example, in U.S. Patent Nos. 4,674,290; 5,183,866; 5,455,314; 5,565,174; 6,045,661; 6,051,631; 6,114,501; and 6,262,191, which are incorporated herein by reference.

[0019] In a loop reaction zone where monomer is polymerized to form solid polymer particles in a diluent, the monomer concentration in the loop reaction zone will tend to vary as the fluid slurry flows around the loop reactor, at least in part due to the conversion of monomer to polymer as the desired result of the polymerization process. As the length of the loop reaction zone increases, the monomer concentration will tend to vary to a greater extent if the monomer is all fed to the loop reaction zone at one location, as it conventionally is. For example, in an 18,000-gallon loop reactor being used for the slurry polymerization of ethylene, there is approximately 48,000 pounds (about 18,000 kilograms) of liquid with approximately 2,200 pounds (about 800 kilograms) of ethylene in the liquid. At a production rate of approximately 40,000 lbs/hr (about 15,000 kg/hr),

the process consumes approximately 333 lbs (about 125 kg) of ethylene in the time it takes to flow around the reactor loop. The ethylene concentration in the loop is calculated to range between about 4.27 wt % just before the ethylene feed point to about 4.93 wt % just after the ethylene feed point. A 35,000-gallon loop reactor may have the same diameter but may be about twice as long as an 18,000-gallon loop reactor. At a production rate of about 88,000 lbs/hr (about 33,000 kg/hr), the process consumes about 1,467 pounds (about 550 kilograms) of ethylene. The reactor contains about 93,300 pounds (about 68,300 kilograms) of liquid with approximately 4,200 lbs (about 1,567 kg) of ethylene. In such a reactor, the ethylene concentration in the loop reactor is calculated to range from about 3.72 wt % just before ethylene feed point to about 5.28 wt % just after the ethylene feed point, if the ethylene is all introduced at a single feed point. This constitutes a relatively wide swing in ethylene concentration.

[0020] For some polyethylene products, such as a 0.55 melt index, 0.9505 density copolymer, it is desirable to maintain the ethylene concentration in the range of from about 4 wt % to about 5.5 wt % (which defines a range of 1.5 wt %). For other polyethylene products, such as a 15.5 high load melt index, 0.9360 density copolymer, it is desirable to maintain the ethylene concentration in the range of from about 1.7 wt % to about 2.7 wt % (which defines a range of 1.0 wt %). For most polyethylene products, it is desirable that the ethylene concentrations around the reactor define a range of about 0.65%, alternatively about 0.85% alternatively about 0.95%, alternatively about 1.05%. Alternatively, it is desirable to operate the process so that the ethylene concentration at any point in the reactor is within the standard deviation from the average ethylene concentration. Preferably, the ethylene concentrations around the reactor have a standard deviation of about 0.2%, alternatively less than 0.3%, alternatively less than 0.4%. The present process and apparatus are capable of providing and maintaining these desired ethylene concentrations.

[0021] A small amount of ethylene may also enter the reactor at diluent flush points. Such flush points are not considered "monomer feeds." Flush points include pump seal area(s), catalyst feed points, product take off points, and pressure relief points and they need to remain open for safe and reliable reactor operation with a minimum of polymer

build up in such openings. This flush can contain a percentage of the ethylene that is in the reactor flash gas and recycled to the reactor. The amount of ethylene recycled into the reactor with the recycled diluent usually about 0 to 10 %, with 5 % being typical.

[0022] Excessive swings in ethylene concentration may slightly lower the allowable maximum operating temperature, because in the part of the reactor with higher ethylene concentration, the reaction rate would be higher than in the part of the reactor with lower ethylene concentration. For example, the reaction rate may be approximately 30% in some places. This approximation is based on the reaction rate being proportional to monomer concentration in the reactor. By using the present process and apparatus, the maximum operating temperature may be increased approximately by more than 3.0°F (1.7°C), and the polymerization process may be operated at a temperature of 218.5°F or more for a polymer that otherwise had a reactor temperature maximum of 215.5°F. The maximum operating temperature is that where polymer softens and fouls the reactor, and it also is dependent on type of polymer, stability of the control system and ability of the reactor jacket to remove heat of polymerization.

[0023] In contrast to the polymerization process discussed in U.S. Patent No. 4,789,714, where an additional monomer feed was employed to initiate the formation of additional MWD modes, in the present process and apparatus, additional monomer feeds may be used to prevent the expansion of the molecular weight distribution of the polyolefin made by the process by maintaining the ethylene concentration at a consistent level. This allows the same high quality product to be made in a large reactor as has been obtained in smaller reactors. The present process and apparatus may be used to produce solid polyolefin particles having a molecular weight distribution that is unimodal.

[0024] Referring now to the drawings, FIG. 1 shows a loop reactor 10 having major segments 12, upper minor segments 14 and lower minor segments 16. The minor segments may simply be curved elbows that join the major segments. Preferably, the lower minor segments are relatively curved to facilitate continuous take-off of product slurry. In FIG. 1, the loop reactor has eight major segments, although the inventors contemplate that the present process and apparatus may be used with a loop reactor having a higher or lower number of major segments, for example, a loop reactor having

four legs or twelve segments. It will be understood that the particular numbering of segments herein does not necessarily imply a priority to the legs, as the loop reactor is circular. FIG. 1 shows the major segments as the first leg 1, second leg 2, third leg 3, fourth leg 4, fifth leg 5, sixth leg 6, seventh leg 7, and eighth leg 8. The first through eighth legs are all surrounded with cooling jackets 18 for heat exchange, that is, for removing at least some of the heat of the polymerization reaction from the loop reactor and providing a means for controlling the temperature of the loop reactor contents.

[0025] The upper and lower minor segments define upper and lower zones of minor flow. Each segment or leg is connected to the next segment or leg by a smooth bend or elbow 20, thus providing a continuous flow path substantially free from internal obstructions. As depicted in Figure 1, some upper and lower minor segments may consist of smooth bends or elbows, so that the minor segment forms a continued curve. The fluid slurry is circulated by means of impeller (not shown) driven by motor 24.

[0026] Monomer (which may be mixed with a diluent) is supplied to the reactor through two monomer feeds (illustrated as the connection of conduit 30 to the loop reactor) from one or more monomer sources 26, which may be a fresh ethylene supply or unreacted ethylene recycled from the slurry taken off from the reactor. Conduits 30 are equipped with flow control valves 32 that control the amount of monomer fed to the loop reactor. The monomer feed may be any known means for feeding monomer to a reactor, such as a simple opening, a nozzle, a sparger, or other fluid distribution apparatus.

[0027] As shown in FIG. 1, two separate monomer control schemes are used to control the two separate monomer feeds. If only one control scheme were used to control multiple monomer feeds, there would be a risk that polymer build-up could cause all of the monomer flow to go through one feed. The control schemes shown in FIG. 1 control the monomer feed to the loop reactor based on the measured concentration of monomer in the portion of slurry withdrawn at a downstream take-off point. Alternatively, the monomer feed may be controlled based on the measured concentration of monomer in the portion of slurry withdrawn at a upstream take-off point or from an average of the measured concentration of monomer in the slurry from several take-off points. Alternatively, the monomer concentration may be measured in the flash gas after the two

take-off streams are combined. Alternatively monomer concentration can be measured directly at one or more points in the reactor.

[0028] Conduits 30 may be adapted to provide flow of feedstock materials in addition to monomer, such as comonomer and/or make-up diluent. Flow control valves 32 are adjusted by flow rate controllers 38, which receive a control signal from a computer 42. Analysis transducers 40 are adapted to analyze samples of slurry from the loop reactor and to deliver, in response to the analysis of the monomer-containing stream, a monomer concentration signal to computer 42. Computer 42 receives as an input the monomer concentration signal and optionally other inputs, such as an operator entered signal which is representative of the desired monomer concentration. Although two computers (one for each monomer control scheme) are shown in FIG. 1, a single computer capable of individual control of the two or more control schemes may be employed. Separate control valves and loops for each monomer feed are to ensure a constant split (50/50 in case of an 8-leg, symmetrical arrangement). Each controller does not need to react to separate effluent monomer concentrations.

[0029] As shown in FIG. 1, the monomer feeds and product take-offs are arranged symmetrically around the loop reactor. An advantage of this symmetrical arrangement is that the monomer concentration may be expected to be approximately or exactly the same at each product take-off (assuming that the amount of monomer fed at each feed point is about the same and the loop reactor is functioning properly). It is easier to control the process if the monomer concentrations at the product take-offs are expected to be about the same.

[0030] Comonomer may also be introduced via conduit 30 or via another feed location. Preferably, a plurality of comonomer feeds are arranged symmetrically around the loop reactor and are part of a control scheme similar to (or incorporated into) the control scheme shown for the monomer feeds.

[0031] Catalyst is introduced via conduits to catalyst feeds 44 which each provide a zone (location) for catalyst introduction. In the embodiments shown in FIG. 1, the catalyst feeds 44 are also symmetrically arranged around the reactor. Alternatively or additionally, the process and apparatus disclosed in U.S. Patent No. 6,262,191

(previously incorporated by reference) for preparing a catalyst mud and providing it a loop reaction (polymerization) zone may be used with the present process and apparatus.

[0032] Dash lines, which designate signal lines in the drawings, are electrical or pneumatic in this preferred embodiment. However, mechanical, hydraulic, or other signal means for transmitting information are also applicable. In almost all control systems, some combination of these types of signals will be used. However, the use of any other type of signal transmission, compatible with the process and equipment in use is within the scope of the invention.

[0033] The loop reactor apparatus of FIG. 1 further comprises means for removing a portion of the slurry from the reactor (product take-offs). The means for removing the slurry portion may be a settling leg, a hollow appendage for continuous take-off, or another conduit for removing the product slurry without substantial leakage or interference with loop reactor operation. Settling legs have long been used in this field and are described in U.S. Patent Nos. 3,293,000 and 4,613,484, which are incorporated herein by reference. In the embodiment shown in FIG. 1, elongated hollow appendages for continuously taking-off an intermediate product slurry are designated by reference character 34. Continuous take-off mechanism 34 is located in or adjacent to one of the lower horizontal reactor loop sections 16, and/or adjacent or on a connecting elbow 20. Additional detail regarding the continuous take-off mechanism is disclosed in Hottovy et al. U.S. Patent No. 6,239,235, which is incorporated herein by reference.

[0034] The withdrawn slurry portion is passed through conduit 36 to a means for separating the solid polyolefin particles from the diluent and unreacted monomer. Conduit 36 may include a surrounding conduit containing a heated fluid which provides indirect heating to the product slurry in conduit 36. Such an arrangement is referred to as flashline heating. The solid polyolefin particles are separated using a two-stage flash design, such as is broadly disclosed in Hanson and Sherk, U.S. Pat. No. 4,424,341 (Jan. 3, 1984), which is hereby incorporated by reference. By using such a design, it is expected that 70 to 90 percent or more of the diluent can generally be recovered in a high pressure flash.

[0035] For example, in a vessel in which the polymer (fluff) is collected in the bottom by gravity and the diluent and unreacted monomer and co-monomer are separated and exit the top. The vessel operates at a pressure high enough such that substantially all of the exiting vapors can be condensed with cooling water and recycled back to reactor by means of a pump. Vaporized monomer diluent may be subject to further processing which includes condensation by simple heat exchange using a recycle condenser, and return to the system, without the necessity for compression, via recycle diluent line. Recycled monomer may be returned to monomer source 26.

EXAMPLES

Example 1

[0036] An 18,000-gallon loop reactor is used for the slurry polymerization of ethylene. The pipe forming the loop reactor has a nominal diameter of 24 inches and is approximately 860 feet in total length. There is approximately 48,000 pounds (about 18,000 kilograms) of liquid with approximately 2,200 pounds (about 800 kilograms) of ethylene in the liquid. At a reactor production rate of approximately 40,000 lbs/hr (about 15,000 kg/hr), the reactor consumes approximately 333 lbs (about 125 kg) of ethylene in the time it takes to flow around the reactor loop. The ethylene concentration in the loop reactor varies from about 4.27 wt % (2,200 pounds of ethylene minus one-half of 333 pounds, divided by 48,000 pounds of liquid contents in the reactor) just before the ethylene feed, to about 4.93 wt % (2,200 pounds of ethylene plus one-half of 333 pounds, divided by 48,000 pounds of liquid contents in the reactor) just after the ethylene feed.

Example 2

[0037] A 35,000-gallon loop reactor is used for the slurry polymerization of ethylene. This reactor has the same diameter but is about twice as long as the 18,000-gallon loop reactor of Example 1. The reactor only has one ethylene feed. The reactor contains about 85,916 pounds (62,900 kilograms) of liquid with 3,437 lbs (1,282 kg) of ethylene. The reactor produces about 87,500 lbs/hr of polymer. The slurry takes approximately 48 seconds to flow completely around the 35,000-gallon loop reactor. In 60 seconds, the reaction consumes about 1,458 pounds (547 kilograms) of ethylene. In this reactor, the ethylene concentration in the loop reactor varies from about 3.32% wt % (3,437 pounds of ethylene minus one-half of 1167 pounds, divided by 85,916 pounds) just before the ethylene feed, to about 4.68% (3,437 pounds of ethylene plus one-half of 1167 pounds, divided by 85,916 pounds) just after the ethylene feed point.

Example 3

[0038] Reactor characteristics of a 35,000-gallon loop reactor such as that shown in FIG. 1 and process characteristics for the polymerization of ethylene are shown in Table 1. The INPUT column refers to values selected by the operator of the loop reactor; the OUTPUT column refers to values determined by the INPUT values and the nature of the reactor and process. Calculations of material balances for ethylene polymerization with one monomer feed and with two monomer feeds are provided in Tables 2 and 3, respectively.

TABLE 1
REACTOR AND PROCESS CHARACTERISTICS

		INPUT	OUTPUT
Reactor Dimensions			
Inner Diameter Shell	inches	22.0625	-
Flow Area	square feet	-	2.6548
Total Leg Length	feet	1,616	-
Number Of Elbows		16	-
Elbow Radius	feet	6.00	-
Elbow Length	feet	-	9.42
Total Length Of Reactor	feet	-	1,756
Reactor Volume	gallons	35,116	-
Pump Section Properties			
Reactor Solids	wt%	48.0%	-
Reactor Temperature	F	214.0	-
Particle Solid Volume Fraction		0.91	-
Solid Density	cc/gm	0.9540	-
	lbs/ft3	-	59.50
Reactor Fluid Density	cc/gm	-	0.409
	lbs/ft3	25.56	-
Reactor Slurry Density	lbs/ft3	-	35.1965

TABLE 1 (CONTINUED)

Reactor CTO Discharge			
Production Rate	lbs PE/hr	87,500	-
CTO Solids	wt%	50.0%	-
CTO Ethylene	wt%	4.0%	-
Slurry Discharge Rate	lbs/hr	-	175,000
Liquids Discharge	lbs/hr	-	87,500
Ethylene Discharge	lbs/hr	-	3,500
Reactor Feed and Contents			
Ethylene Feed (Assume Homopolymer)	lbs/hr	-	91,000
Recycle Liquids Feed	lbs/hr	-	84,000
Reactor Slurry Amount	lbs	-	165,224
Reactor Liquids Amount	lbs	-	85,916
Reactor Solids Amount	lbs	-	79,308
Reactor Ethylene Amount	lbs	-	3,437

TABLE 1 (CONTINUED)

Reactor Circulation And Reaction			
Reaction Rate	lbs/min		1,458
Reaction Circulation Rate	gpm	43,800	
Reaction Circulation Rate	ft ³ /min		5,856
Velocity	ft/min		2,205
Revolutions Per Minute	rpm		1.25
Effective Leg Length	FOTO-WEAR		221
Reaction Per Leg	lbs/min		182

[0039] Table 2 shows calculated values for a 35,000-gallon loop reactor in which ethylene monomer is fed to the reactor through one monomer feed located just after the pump. The right-most column indicates that the concentration of ethylene in the fluid slurry (expressed as the weight percent of ethylene in the fluid slurry) varies from 3.35% to 4.64%, a range of 1.11%, a mean of 3.73%, and a standard deviation of 0.41%

TABLE 2
CALCULATIONS OF MATERIAL BALANCE
FOR LOOP REACTOR HAVING ONE MONOMER FEED POINT

	Ethylene	Isobutane (all other liquids)	Total Liquids	Polyethylene	Total Slurry	Solids	Ethylene
	lbs/min	lbs/min	lbs/min	lbs/min	lbs/min	wt%	wt%
Pump	3,589	103,574	107,163	98,920	206,083	48.00%	3.35%
Feed (1.29%)	1,517	1,400	2,917				
Leg 2 Inlet	5,106	104,974	110,080	98,920	209,000	47.33%	4.64%
Leg 3 Inlet	4,923	104,974	109,898	99,102	209,000	47.42%	4.48%
Leg 3 Outlet	4,741	104,974	109,715	99,284	209,000	47.50%	4.32%
CTO	31.5	697.7	729.2	729.2	1,458.3	50.00%	4.32%
Leg 4 Inlet	4,710	104,277	108,986	98,555	207,541	47.49%	4.32%
Leg 5 Inlet	4,527	104,277	108,804	98,738	207,541	47.57%	4.16%
Leg 5 Outlet	4,345	104,277	108,621	98,920	207,541	47.66%	4.00%
Feed (0%)	0	0	0				
Leg 6 Inlet	4,345	104,277	108,621	98,920	207,541	47.66%	4.00%
Leg 7 Inlet	4,163	104,277	108,439	99,102	207,541	47.75%	3.84%
Leg 7 Outlet	3,980	104,277	108,257	99,284	207,541	47.84%	3.68%
CTO	26.8	702.4	729.2	729.2	1,458.3	50.00%	3.68%
Leg 8 Inlet	3,954	103,574	107,528	98,555	206,083	47.62%	3.68%
Leg 1 Inlet	3,771	103,574	107,345	98,738	208,083	47.91%	3.51%
Leg 1 Outlet	3,589	103,574	107,163	98,920	206,083	48.00%	3.35%

[0040] Table 3 shows calculated values for a 35,000-gallon loop reactor in which ethylene is fed through two monomer feeds, one located just after the pump and the other located just after the bottom of the fifth reactor leg. In this reactor, the ethylene feeds and the product take-off points (CTOs) are symmetrically arranged. The right-most column in Table 3 indicates that the concentration of ethylene in the fluid slurry varies from 3.67 wt % to 4.32 wt. %, with a range of 0.65%, a mean of 3.74%, and a standard deviation of 0.21%.

TABLE 3
CALCULATIONS OF MATERIAL BALANCE FOR LOOP
REACTOR HAVING TWO MONOMER FEED POINTS

	Ethylene	Isobutane (all other liquids)	Total Liquids	Polyethylene	Total Slurry	Solids	Ethylene
	lbs/min	lbs/min	lbs/min	lbs/min	lbs/min	wt%	wt%
Pump	3,937	103,227	107,163	98,920	206,083	48.00%	3.67%
Feed (0.65%)	758	700	1,458				
Leg 2 Inlet	4,695	103,927	108,621	98,920	207,541	47.66%	4.32%
Leg 3 Inlet	4,513	103,927	108,439	99,102	207,541	47.75%	4.16%
Leg 3 Outlet	4,330	103,927	108,257	99,284	207,541	47.84%	4.00%
CTO	29.2	700.0	729.2	729.2	1,458.3	50.00%	4.00%
Leg 4 Inlet	4,301	103,227	107,528	98,555	206,083	47.82%	4.00%
Leg 5 Inlet	4,119	103,227	107,345	98,738	206,083	47.91%	3.84%
Leg 5 Outlet	3,937	103,227	107,163	98,920	206,083	48.00%	3.67%
Feed (0.65%)	758	700	1,458				
Leg 6 Inlet	4,695	103,927	108,621	98,920	207,541	47.66%	4.32%
Leg 7 Inlet	4,513	103,927	108,439	99,102	207,541	47.75%	4.16%
Leg 7 Outlet	4,330	103,927	108,257	99,284	207,541	47.84%	4.00%
CTO	29.2	700.0	729.2	729.2	1458.3	50.00%	4.00%
Leg 8 Inlet	4,301	103,227	107,528	98,555	206,083	47.82%	4.00%
Leg 1 Inlet	4,119	103,277	107,345	98,738	206,083	47.91%	3.84%
Leg 1 Outlet	3,937	103,227	107,163	98,920	206,083	48.00%	3.67%

[0041] Tables 2 and 3 (in particular, the calculation of ethylene concentration in the last column of each table) demonstrate that the use of a system having two monomer feeds leads to a more consistent monomer concentration within the loop reactor.

[0042] While this invention has been described in detail for the purpose of illustration, it is not to be construed as limited thereby, but is intended to cover all changes within the spirit and scope thereof.